Technical Report

September 1994

Long-Term Tests of Some Inexpensive Barometers
and
Results of Pressure Cycling of an AIR-DB-1A

by

Richard E. Payne

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Results of Pressure Cycling of an AIR-DB-1A

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Abstract

For approximately 1.5 years, daily observations of barometric pressure were made with a variety of sensors and compared to readings from a Paroscientific Model 760-16B while all sensors were maintained at a temperature of 20 C ± 2°C. The results of two samples from each of three inexpensive (strain gauge integral to a silicon chip) pressure sensors are reported on. The SenSym Model SCX15AN, Nova PI and the Microswitch Model 134PC15A1 had standard deviations of 0.2, 2.6, and 5.6 mb, respectively. The SenSym amd Nova sensors had drift rates of 0.5 and 0.9 mb per year, respectively. A fourth sensor, the Microswitch, had output that was too noisy for a meaningful computation of drift rate. Neither of the Omega Model PX93-015GV samples operated properly. The excellent results indicate that strain gauge sensors are worth considering for measuring barometric pressure in situations where the highest accuracy is not required. Temperature effects, which can be substantial in strain gauge sensors, were not investigated.

Pressure cycling tests of an AIR Model DB-1A show that cycles of 3–10 psi above ambient pressure do not affect the accuracy of the sensor, even after millions of cycles. Therefore, rough weather conditions at sea, i.e., waves washing over the barometer port on a drifting buoy, are unlikely to cause inaccuracy in an AIR sensor.

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1. Introduction

The IMET (for Improved METeorological sensing and recording) system was developed by the Upper Ocean Processes Group (UOP) at the Woods Hole Oceanographic Institution (WHOI) for measuring the surface meteorological parameters required for the computation of heat and momentum fluxes at the sea surface from buoys (Hosom *et al.*, 1994). Barometric pressure enters into the computations indirectly but is significant. Tests of high-quality electronic barometers were reported in Payne (1994) and Payne *et al.* (1989). In this report long-term comparisons of some inexpensive pressure sensors with a Paroscientific Model 760-16B are described. The results of pressure cycling on an AIR Model DB-1A are also described.

2. Sensors and Circuits

Some inexpensive pressure sensors were included in the original comparison study because a great deal of development has gone into them in recent years and we were curious to learn how well they might perform. The four that were chosen cover the price range from $15 to $100. There are an enormous number of sensors on the market in this price range, and no attempt was made to select the best at each price level. This would have involved a large effort for what was a peripheral interest. The four that were chosen were readily and conveniently available.

The sensors described in this report, with some of their pertinent parameter values as gleaned from manufacturer's literature, are listed in Table 1.

Table 1. Sensor Parameters

Sensor Manufac.	Microswitch	SenSym	Nova	Omega
Sensor Model	134PC15A1	SCX15AN	PI	PX93-015GV
Case Material	Nylon	Nylon	SS	SS
Excitation-volts	10 V	18 Vmax	NS	NS V
Excitation-ma	2.0	NS	1.0	1.5 ma
Full Scale Output	100 mV	90 mV	100 mV	100 mV
Repeat.& Hysteresis	± 0.15	± 0.1	± 0.35	0.25 %FSO
Stability–1 year	± 0.5	± 0.1	± 0.2	NS %FSO
Sens. shift-25°C	±6.5	±0.2	±1	± 0.3 %FSO
Approximate price	$15	$40	$75	$100

All four of the sensors contain strain gauges on a silicon chip arranged in a Wheatstone bridge configuration and have a pressure range of 0–15 psi. Each chip includes, as well, some temperature compensation although it is generally not sufficient to allow the chip to handle a wide temperature variation without degrading its accuracy. Two of each sensor were purchased to ensure that we did not generalize from an anomalous sensor.

3.   Initial Calibrations

Since none of these sensors come calibrated and, indeed, the output voltage at a given pressure depends on the supply voltage, the first month's data taken simultaneously with the readings from a Paroscientific Lab Standard (PLS), Model 760-16B was used as a calibration data set. This data set covered a range of pressures of 985–1040 mb. There were very few excursions beyond this range in the data recorded during the subsequent comparison period. A least squares linear fit was made of each sensor's ratios of output voltage to supply voltage to the PLS readings. The PLS, except for a problem which was repaired before the comparison study began, has been stable and precise to better than ± 0.05 mb. It has been returned to Paroscientific annually for calibration checks.

4.   The Data

Beginning on 6 September 1990, and continuing until 25 February 1992, the voltage output of each sensor as well as its supply voltage and the PLS reading were recorded daily except for weekends, a total of 433 data points. An attempt was made earlier to record the data using an A/D board in a PC but the accuracy was not sufficient for some other sensors (Payne, 1994). Subsequently the sensor and supply voltages were measured with a Hewlett Packard Model 3478A DMM (digital multimeter). Barometric pressures were computed using the linear fits developed during the initial calibration. Two files were produced: the file of computed barometric pressures with the PLS pressure, and a file of the differences between the computed pressures and the PLS pressures. These two files form the basis of our analysis.

The sensors resided in a room whose temperature was controlled to ± 2°C for the entire period of the comparison. Any disagreement with the PLS data, therefore, comes either from random errors or shifts in the calibrations with time or for other reasons. It is necessary to emphasize that the strain gauge pressure sensor can be highly temperature dependent. The temperature dependence can, at least in principle, be compensated for

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electronically. Because systematic shifts with time and random errors were much more difficult to handle, these problems were studied and temperature effects were ignored.

Figure 1 is a plot of all the PLS pressures against year day to show the basic data set. For each type of sensor two plots are given for each of the two samples: a scatter plot of sensor computed pressure against PLS pressure to show how well the sensor reported barometric pressure and a plot of the difference between sensor and PLS pressure against year day to show random and time correlated effects.

5. Test Results

5.1 Microswitch Model 134PC15A1

The data from the Microswitch sensors are shown in Figures 2 and 3. A least squares fit of the scatter plot data yields

$$BP = 336.2 + .66824 * MSA \quad SD = 5.6 mb$$

$$BP = 350.0 + .65473 * MSB \quad SD = 5.7 mb$$

where MSA and MSB represent the sensor observations in mb and SD indicates the standard deviation about the PLS observations. For perfect agreement with the PLS the bias would be 0.0 and the slope 1.0000. Apparently our initial calibration data were inadequate for this sensor. The standard deviation shows that even a revised calibration would not result in a sensor which was useful for measuring barometric pressure in any scientific context. Because of the large noise level it was not meaningful to compute a drift rate.

5.2 SenSym Model SCX15AN

The data from the SenSym sensors are shown on Figures 4 and 5. A least squares fit of the scatter plot data yields

$$BP = 0.2 + 0.99984 * SSA \quad SD = 0.2$$

$$BP = -0.2 + 1.00021 * SSB \quad SD = 0.2$$

The drift rates for the two samples were both 0.5 mb per year with a standard deviation of 0.1 and 0.3 mb, quite low.

5.3   Nova PI

The data from the Nova PI sensors are shown in Figures 6 and 7. A least squares fit of the scatter plot data yields

$$BP = 32.2 + .96818 * N165 \quad SD = 2.7$$

$$BP = 28.0 + .97226 * N168 \quad SD = 2.6$$

The drift rates for the two samples were 0.8 and 0.9 mb per year with standard deviations of 2.7 and 2.6 mb, also quite low.

5.4   Omega Model PX93-015GV

Neither of the Omegas gave valid data. They seemed to drift aimlessly for several months until I gave up and removed them from the system. Considerable but futile effort was put into checking connections, power supply voltages, etc.

6.   Comments on the Data

There was one artifact which appeared for which there was no explanation. Between days 452 and 453, or 28 and 29 March 1991, the outputs of the Nova and Microswitch dropped markedly, of order 5 mb. Over the next three months they slowly regained their previous bias relative to the PLS. This is clearly evident in Figures 2B, 3B, 6B and 7B. There were two correlating events. The ambient pressure rose 10 mb, from 994.1 to 1004.5 mb, between day 452 and 453. On day 453 an additional sensor was attached to the power supply, a Heise model HPO. The power supply was the only point of electrical commonality among the sensors but it had ample capacity to handle the load and each sensor had its own voltage regulator.

7.   Pressure Cycling Effects on AIR Barometers

In 1989 Peter Niiler of Scripps Institution of Oceanography requested some tests be conducted on the response of AIR sensors to cycling of pressure above ambient. The application he had in mind was measuring atmospheric pressure on surface drifter buoys with waves washing over the port.

In early May we attached two AIR sensors, serial numbers 58 and 115, to an apparatus which applied a 10 psi pressure pulse with very short rise and decay times about once per second. After approximately 15 hours, or about 29,000 cycles, number 58 failed. Analysis by AIR showed that two voltage regulator chips had failed and there was a burned trace on the digital board. None of these could we attribute to the pressure cycling tests. In June 1988 AIR had replaced the digital board and this was the first use of number 58 since then. The failure was attributed to an early life component failure.

After repair of serial number 58, tests were begun again on 26 July with the same two sensors. This time a 3 psi pulse was applied once per second. On 21 August it was increased to about twice per second. On 11 September the test was terminated after a total of about 5.5 million cycles. There were no further failures. The outputs of the two AIR sensors were compared at approximately weekly intervals with that of the PLS. No shift in calibration of either of the sensors was discernible at the level of accuracy of the PLS, *i.e.*, ± 0.05 mb.

8. Summary

Long-term comparisons of three inexpensive pressure sensors with a Paroscientific Lab Standard barometer showed that one of them has the stability and precision to be used as a barometer in some applications. Since the sensors used in this test were purchased in 1989 and steady advances have been made in the design and manufacture of silicon strain gauge pressure sensors since then, there are probably better inexpensive pressure sensors on the market now. It would be worth considering them for the measurement of barometric pressure in a non-critical application. Since the published specifications provide only an indication of performance in an application, any candidate should be tested thoroughly before being used.

The problem of temperature compensation has not been addressed in this report. Silicon strain gauge pressure sensors do have temperature coefficients. Although internal compensation has improved, use as a barometer would probably require external temperature compensation.

In a separate study, it was determined that pressure cycling of the AIR DB-1A with a magnitude of 3 or 10 psi over ambient has no measureable effect on the barometer when applied for millions of cycles.

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Payne, Richard E., 1994. Long term stability of some barometric pressure sensors. *Journal of Atmospheric and Oceanic Technology*, accepted.

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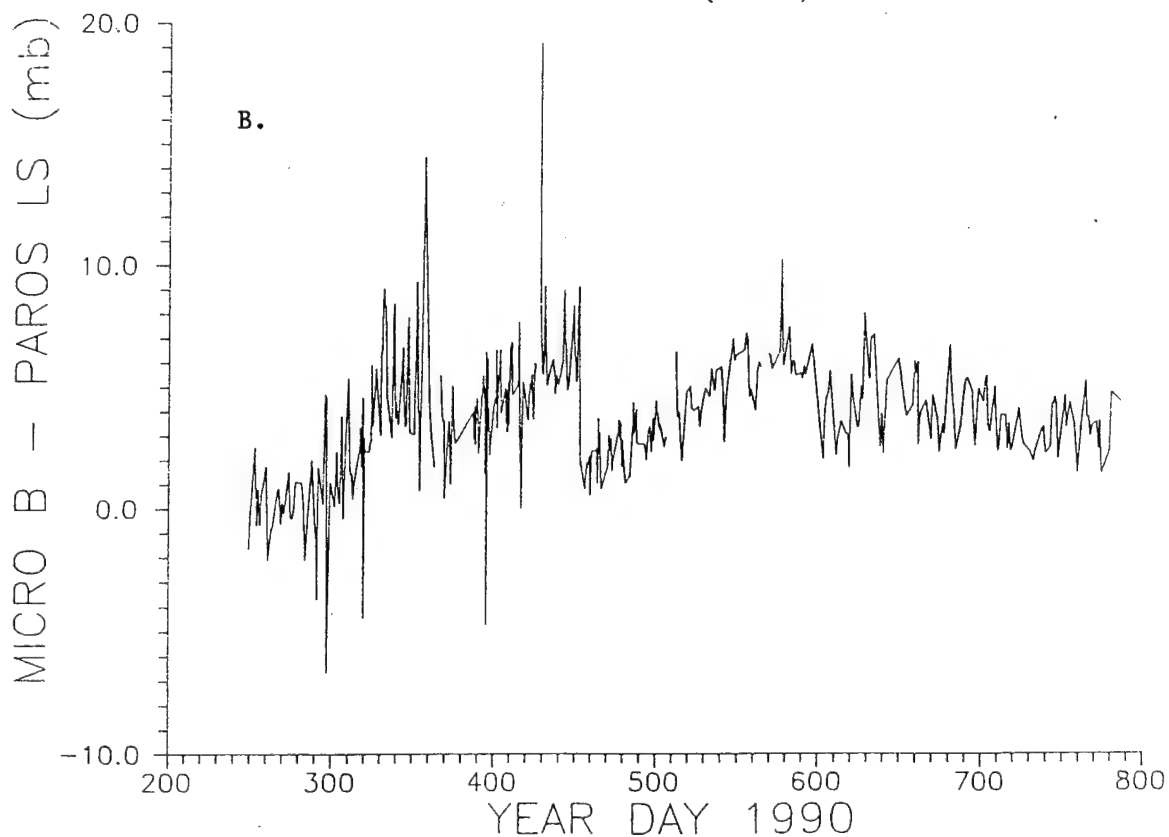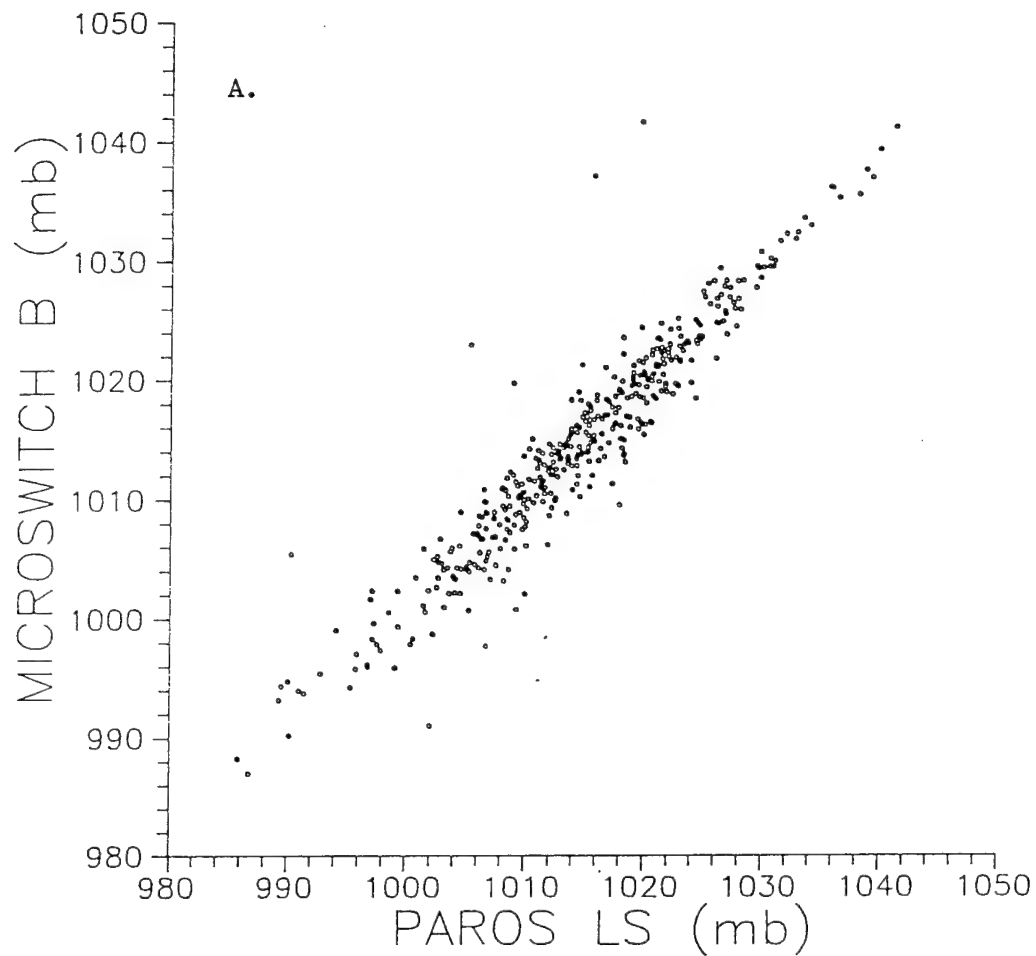
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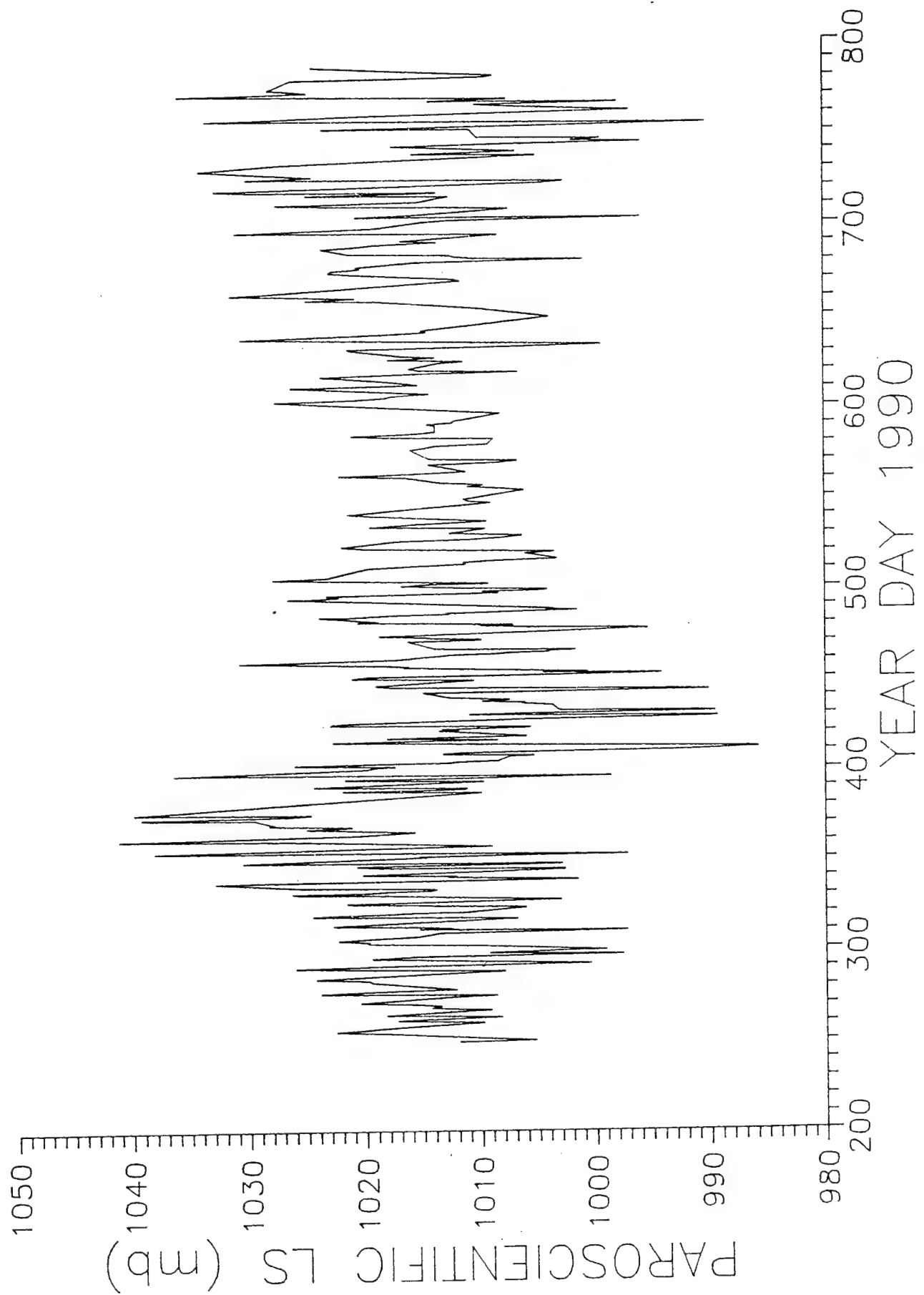
Figure 1. Barometric pressure from a Paroscientific Model 760-16B for the period of the comparison.

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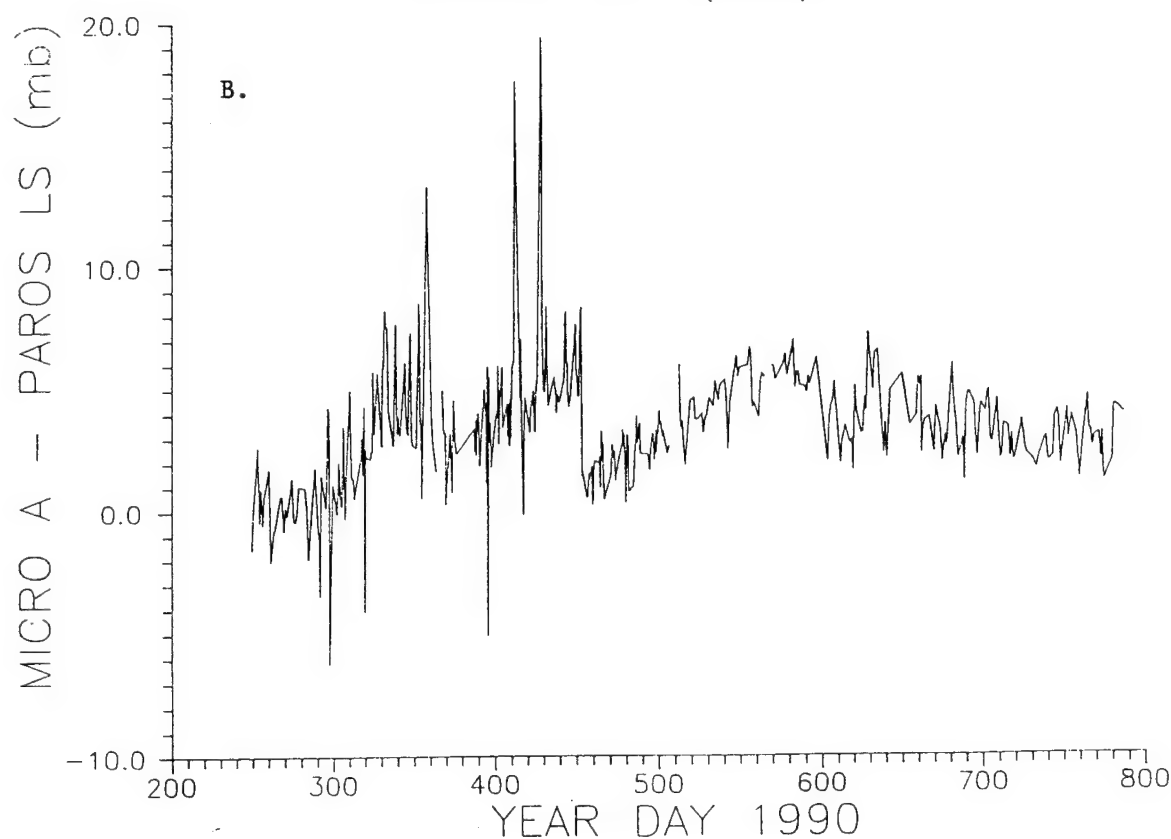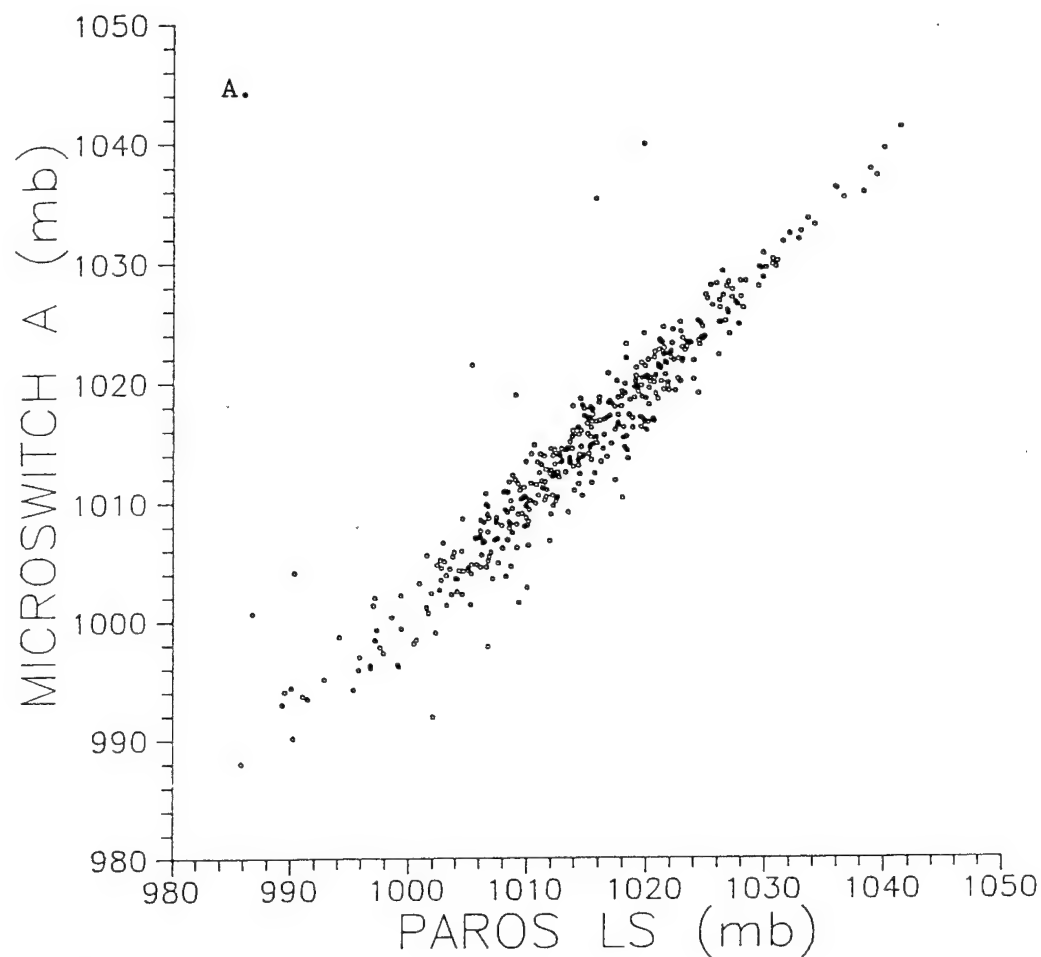
Figures 2A & 2B. A. Sample A of Microswitch Model 134PC15A1 *vs* PLS.
B. Sample A of Microswitch Model 134PC15A1 – difference with PLS *vs* year day.

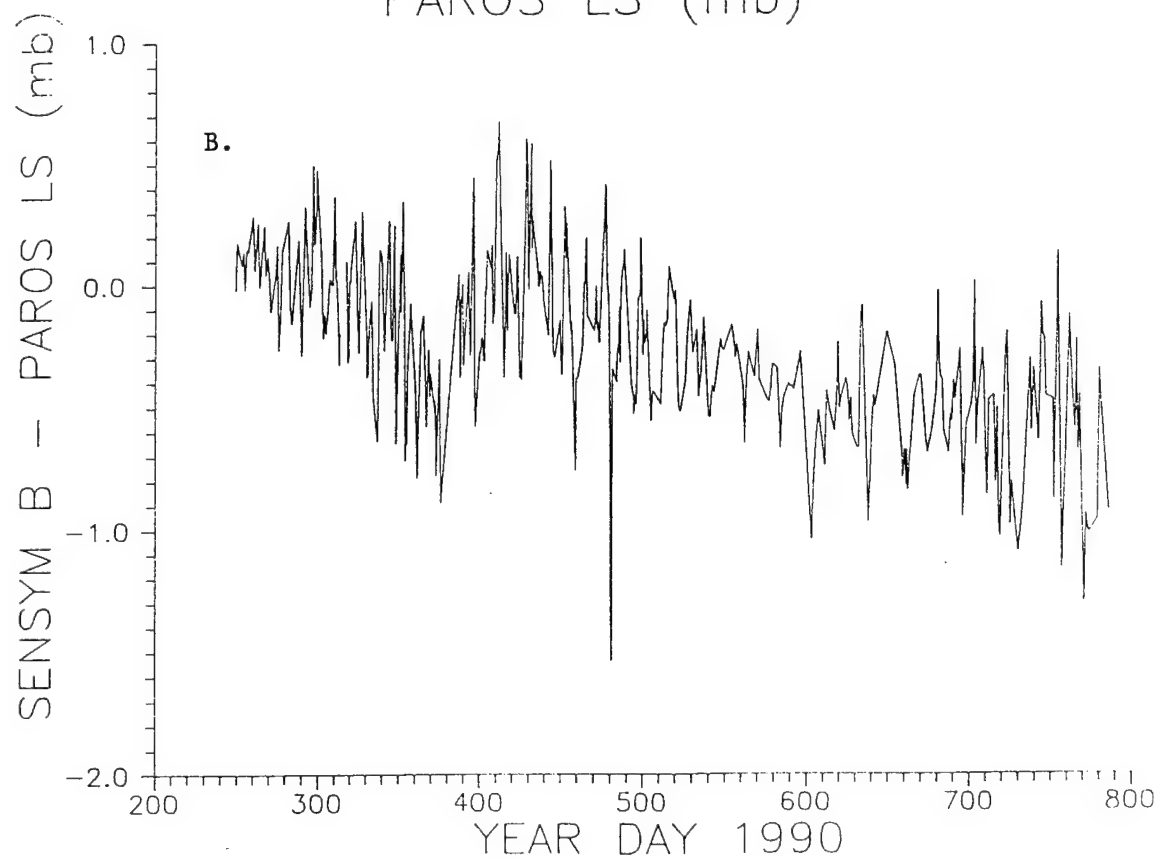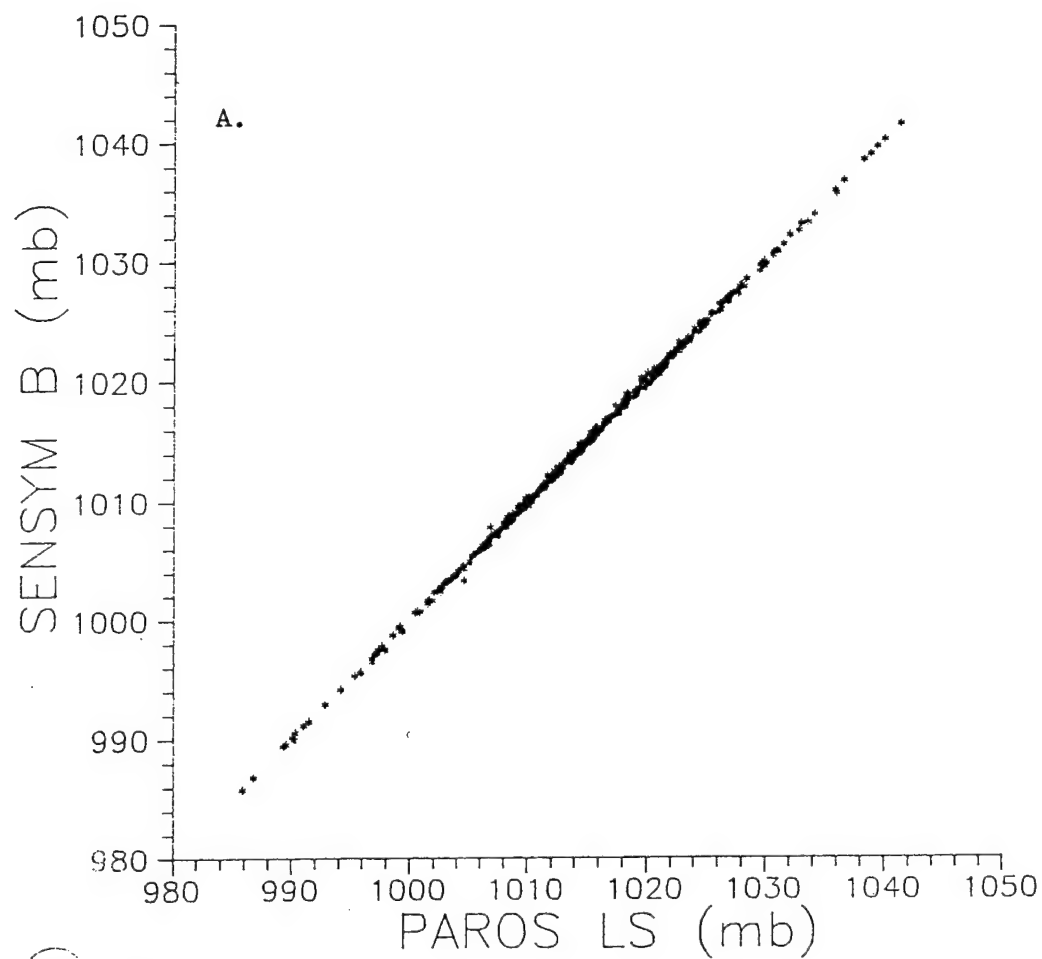**Figures 3A & 3B.** A. Sample B of Microswitch Model 134PC15A1 *vs* PLS.
B. Sample B of Microswitch Model 134PC15A1 – difference with PLS *vs* year day.

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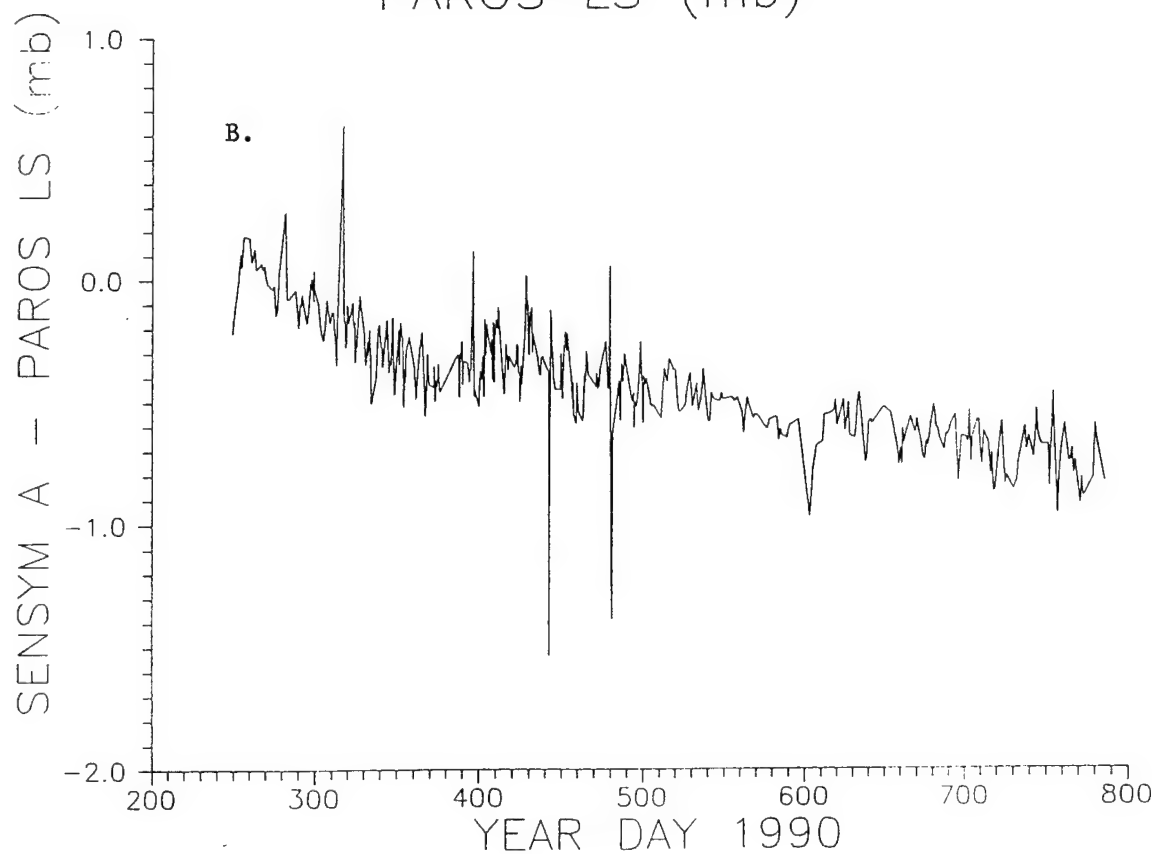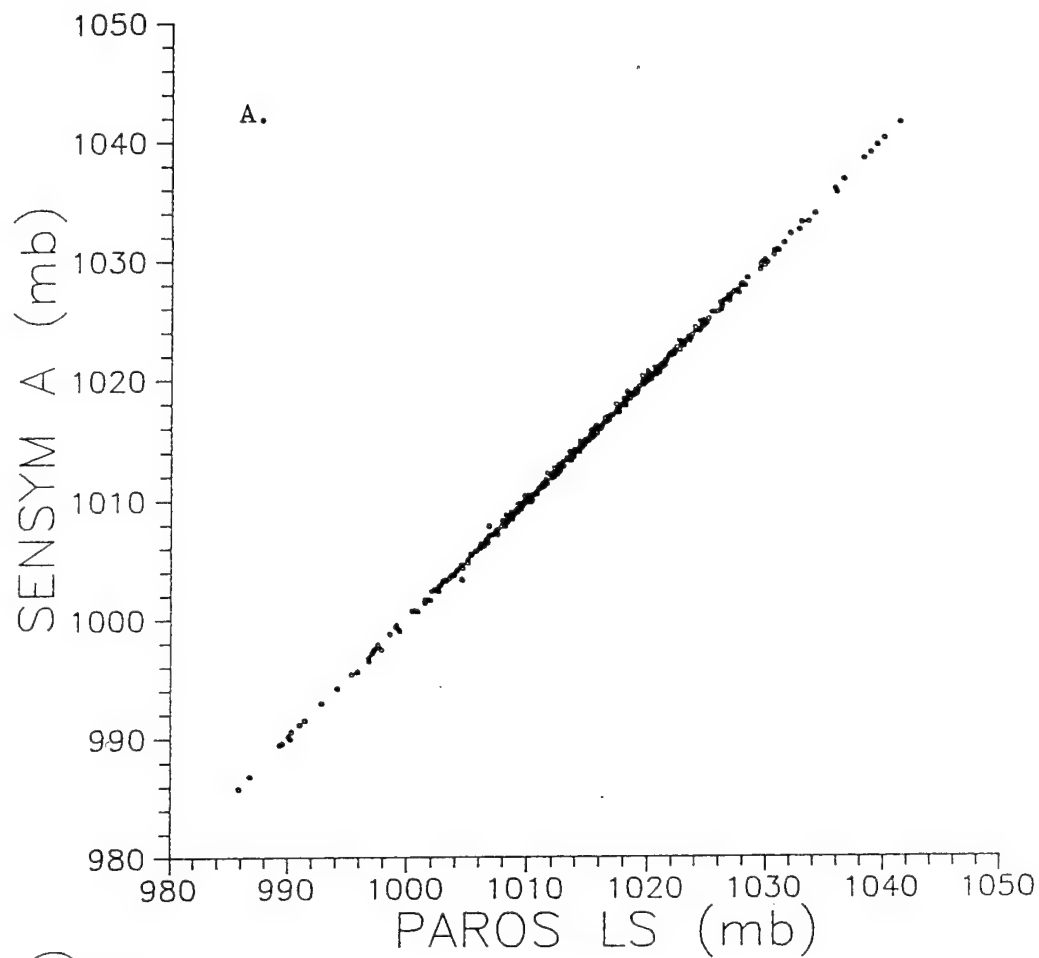
Figures 4A & 4B. A. Sample A of SenSym Model SCX15AN *vs* PLS.
B. Sample A of SenSym Model SCX15AN – difference with PLS *vs* year day.

Figures 5A & 5B. A. Sample B of SenSym Model SCX15AN *vs* PLS.
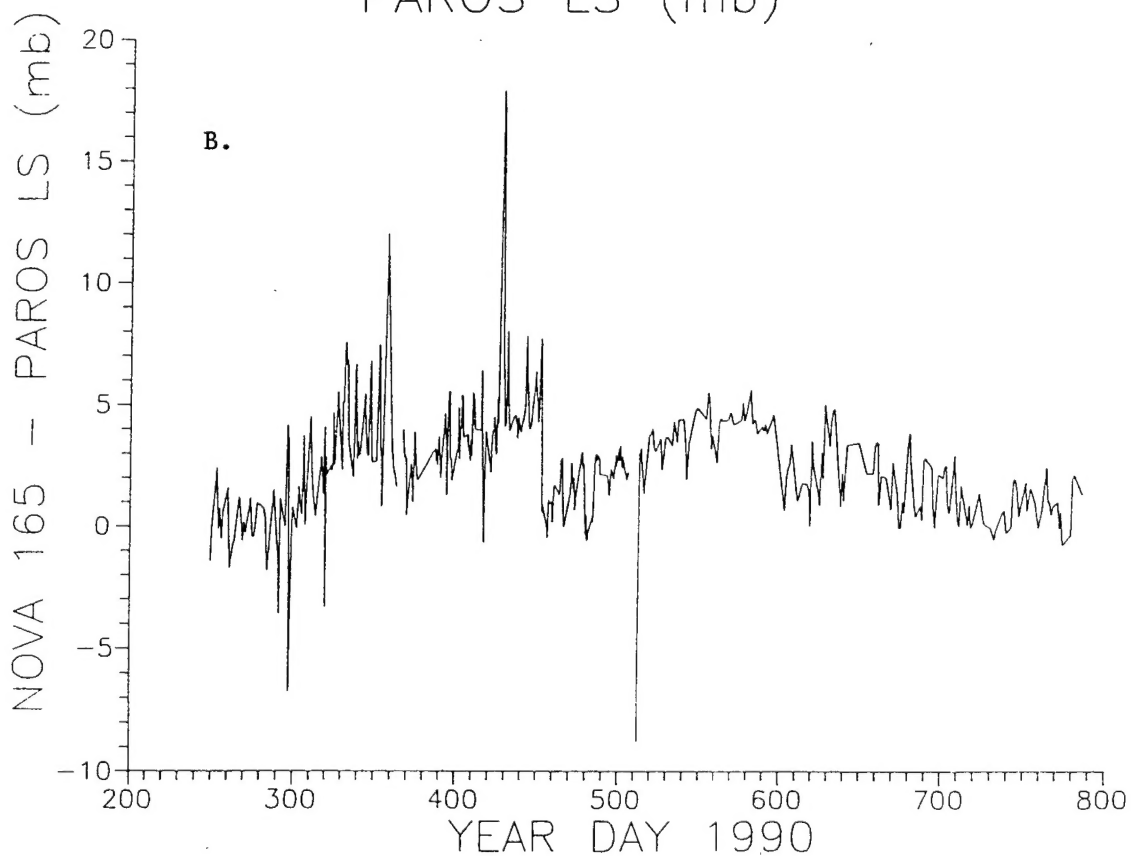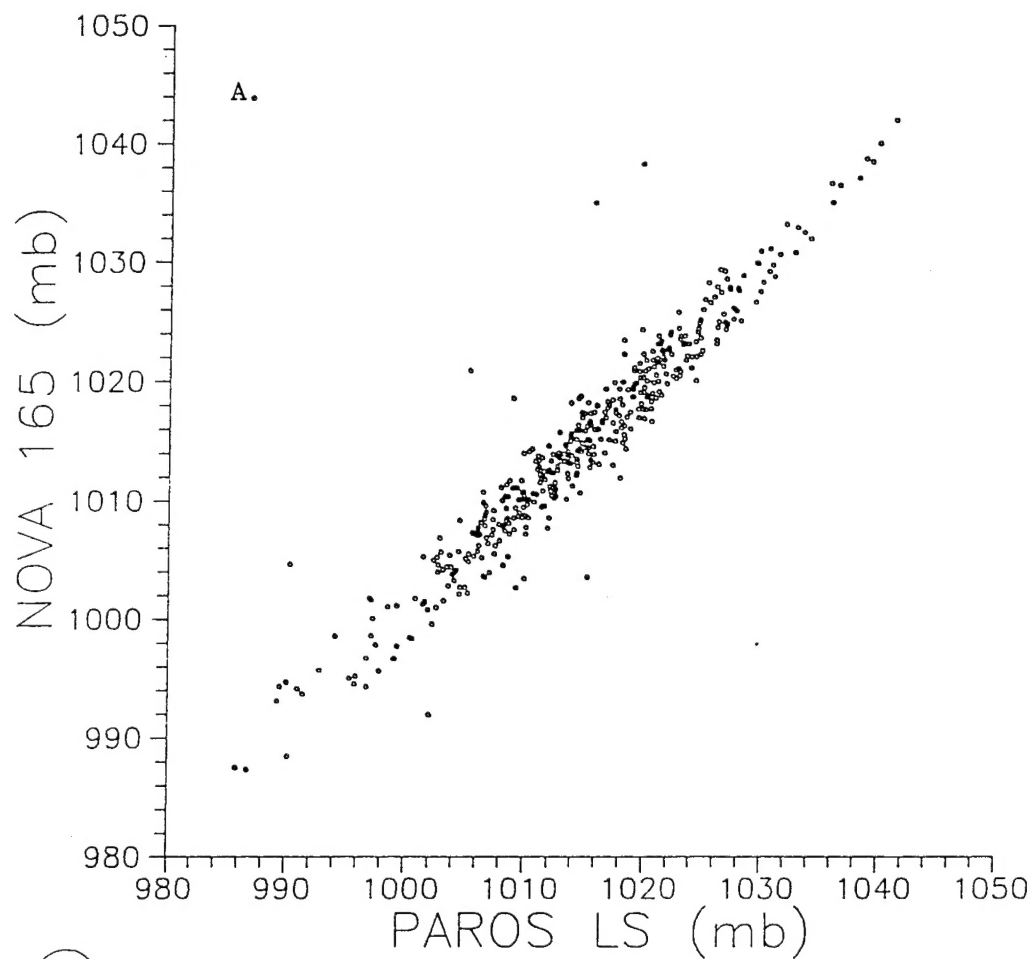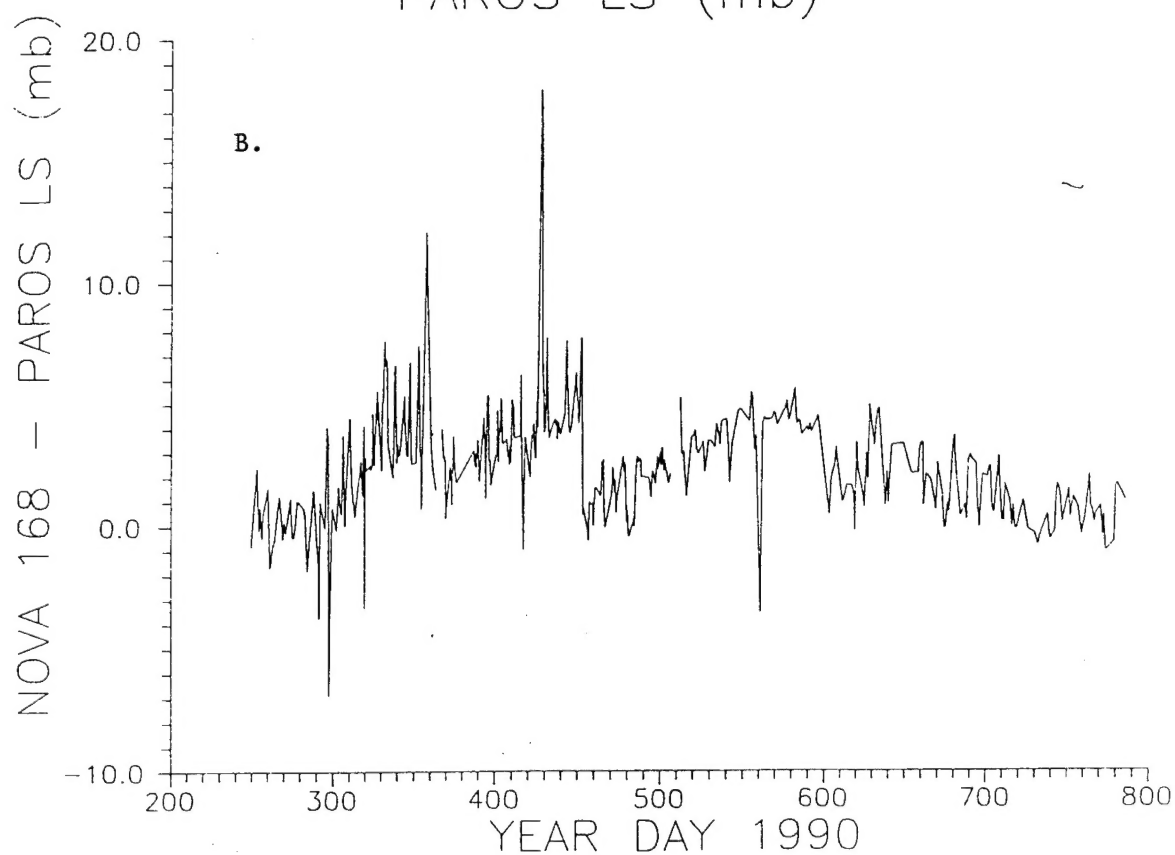B. Sample B of SenSym Model SCX15AN – difference with PLS *vs* year day.
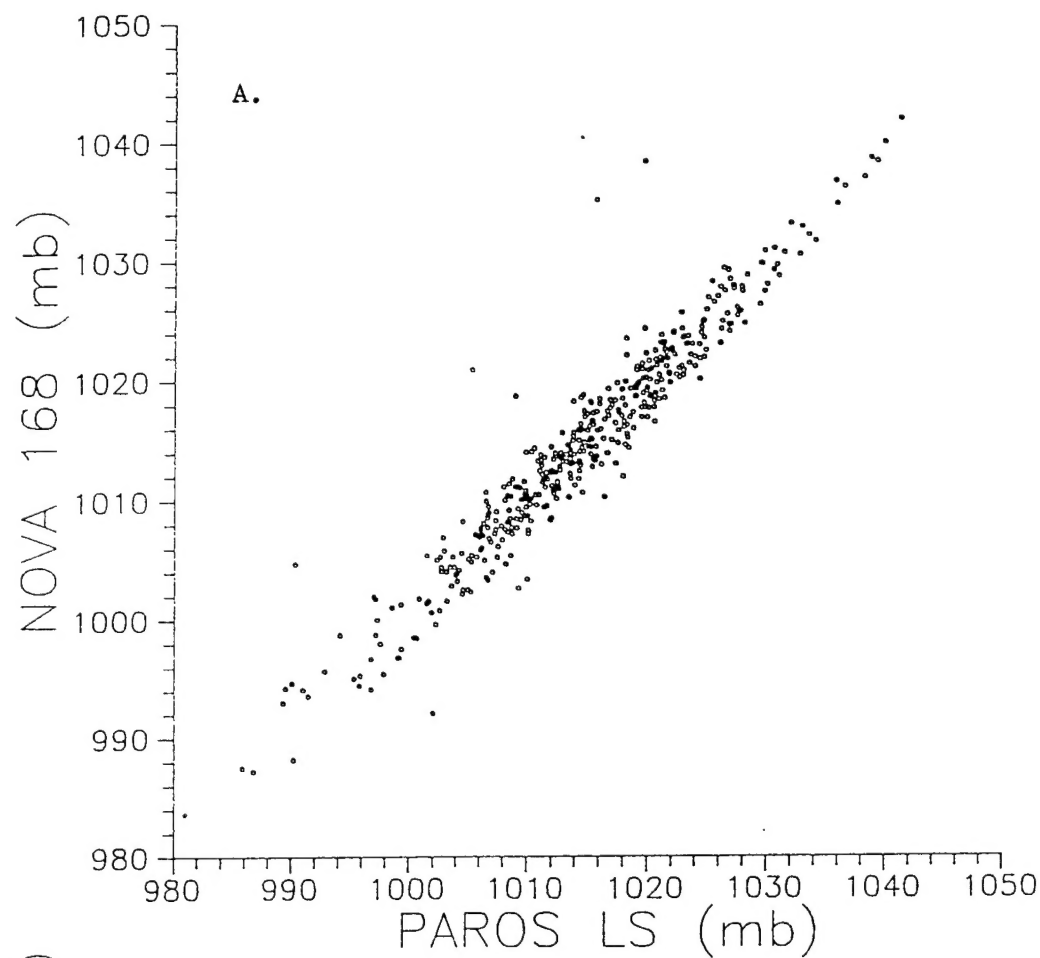
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Figure 6A & 6B. A. Sample A of Nova Model PI *vs* PLS.
B. Sample A of Nova Model PI – difference with PLS *vs* year day.

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Figures 7A & 7B. A. Sample B of Nova Model PI *vs* PLS.
B. Sample B of Nova Model PI – difference with PLS *vs* year day.

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16. Abstract (Limit: 200 words)

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AIR-DB-1A cycling tests

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

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